Issue #2

OPERATING INSTRUCTIONS

FOR THE

TYPE 202-D FREQUENCY MODULATED SIGNAL GENERATOR

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PROCEDURES
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BOONTON RADIO CORPORATION
BOONTON, NEW JERSEY
U. S. A.

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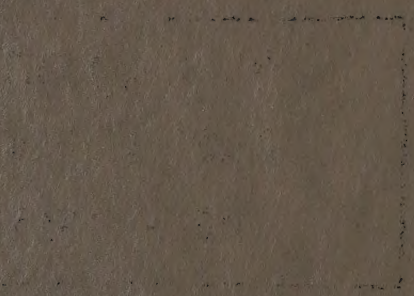

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TYPE 202-D FM SIGNAL GENERATOR

1. INTRODUCTION

a. GENERAL.

The Type 202-D Frequency Modulated Signal Generator has been developed to meet the specialized requirements of engineers working with telemetering receivers and other associated equipment. It is a precise and reliable instrument for rapidly evaluating overall system performance. Provisions have also been made whereby it may be used in this frequency range as an amplitude modulated r-f signal source or, in conjunction with an external audio oscillator, may be used to produce simultaneous FM and AM r-f signals.

Physically this instrument consists of four major subassemblies: (1) panel assembly, (2) r-f assembly, (3) audio oscillator, and (4) regulated power supply.

The r-f unit is secured to the rear of the front panel while the audio oscillator and power supply are fastened to the bottom of the generator cabinet and are electrically connected to the front panel and r-f assembly by means of cables and plug connectors.

The wiring and layout of the various components have been arranged for maximum simplicity resulting in a compact instrument of moderate size, thereby conserving laboratory space. All meters and calibrated controls are direct reading and are located on the front panel according to function. The frequency dial, as well as the modulation meter, has been positioned at eye-level for maximum readability. Exclusive use of aluminum for cabinet, panel and chassis fabrication has resulted in a relatively lightweight, easily portable instrument. For convenience in carrying a collapsible leather handle is attached to the top of the generator cabinet. This instrument is supplied complete with tubes, instruction book, and type 501-A r-f cable.

b. BASIC OPERATING PRINCIPLES (Fig. 1).

Figure 1 shows in block form the basic elements employed in the 202-D Signal Generator. A type 6C4 triode is used as an r-f oscillator and is tuned over the frequency range of 43.75-62.50 megacycles.

Coupled to the r-f oscillator is a 6AK5 reactance tube which, for frequency modulation, shifts the frequency of the oscillator in direct proportion to the instantaneous audio voltage applied to the reactance tube from the audio modulating oscillator.

The output from the r-f oscillator is fed to a Class C frequency doubling stage which is tuned to the second harmonic of the oscillator frequency, thus covering a frequency range from 87.5 to 125.0 megacycles. Following this doubling stage is an output stage which

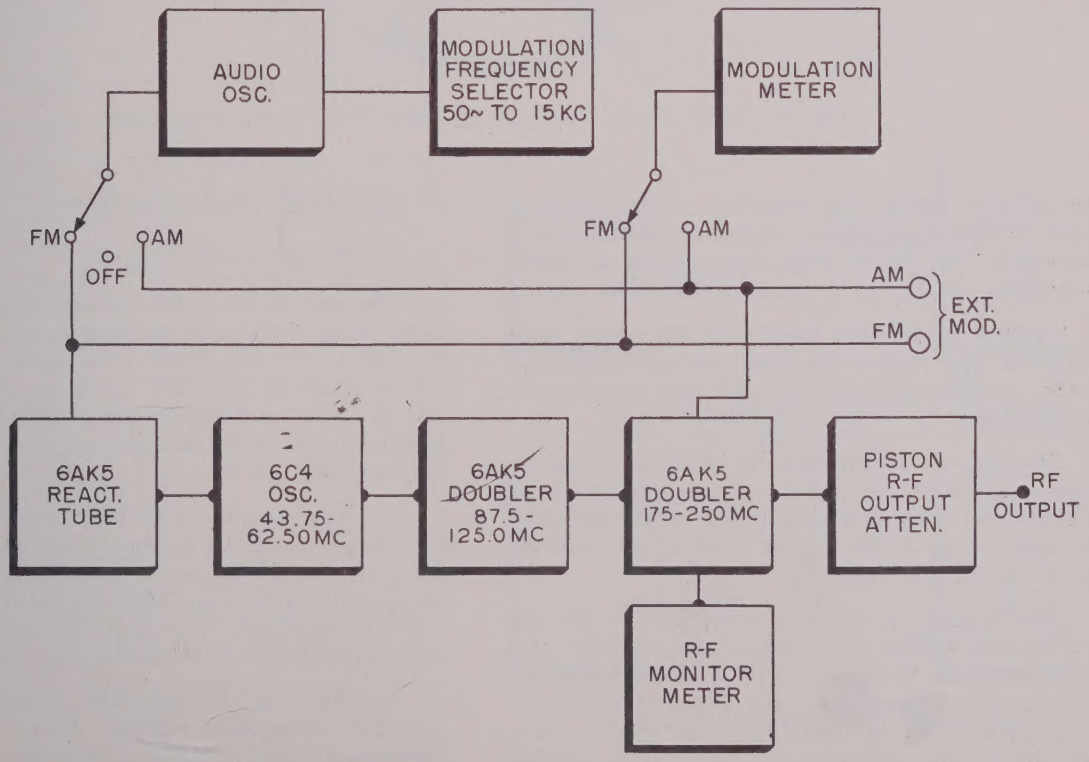


Fig. 1. Basic Elements of 202-D FM Signal Generator

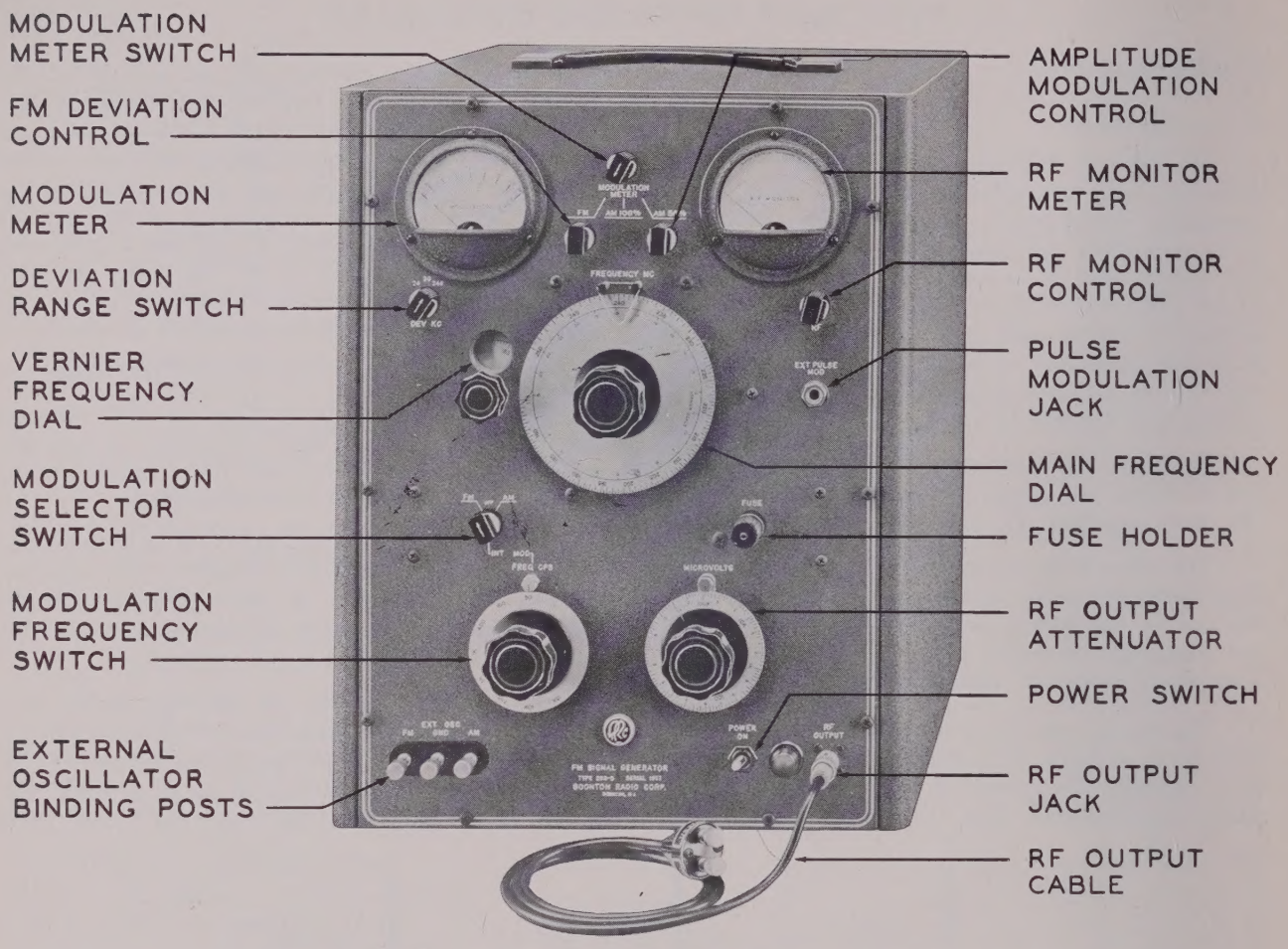


Fig. 2. Front Panel Controls of 202-D FM Signal Generator

also serves to double the frequency of the incoming signal (175-250 megacycles). Amplitude modulation is obtained at this output stage by applying an audio modulating voltage to the screen of the 6AK5 tube.

Coupled to the plate inductor of the output stage is a piston type mutual inductance attenuator having a 53 ohm terminating resistor in series with the one turn coupling loop.

The dial of the attenuator is calibrated in microvolts, in terms of the voltage present at the output cable terminal posts when the power output from the last stage is set to the proper level as indicated by the output monitor meter.

The 53 ohm r-f output is terminated at one end by a 53 ohm resistor and terminal post assembly, and at the other end by a BNC type connector which attaches to the r-f panel jack. The output impedance of the generator with this cable connected is 26.5 ohms. The voltage appearing across the output cable terminal posts is read directly on the output attenuator dial.

2. OPERATING INSTRUCTIONS.

a. PRELIMINARY (Fig. 2).

The instrument should be carefully removed from the packing carton and the power cord plugged into a suitable 115 volt, 50-60 cycle outlet. Operate the Power Switch to the "ON" position. Attach the R-F Output Cable to the front panel R-F Output Jack by pushing in on the cable connector and rotating it clockwise.

Operation of the R-F Monitor Control should cause the pointer of the R-F Monitor Meter to move. It should be possible to set the meter pointer to the red reference mark over the entire frequency range from 175-250 megacycles. This is an indication that the r-f oscillator and amplifiers are working properly.

To check the FM and AM modulating systems, turn the Modulation Selector Switch to FM, the Modulation Meter Switch to FM, and the Deviation Range Switch to 24 kc., 80 kc., or 240 kc. Operating

the FM Deviation Control in a clockwise direction should cause the Modulation Meter to read increasing deviation. Switch the Modulation Selector Switch to AM, the Modulation Meter Switch to AM, and rotate the Amplitude Modulation Control clockwise. The Modulation Meter should read the degree of amplitude modulation present and full-scale setting should be possible.

b. OPERATING CONTROLS (Fig. 2).

This section describes the operating controls which are located on the front panel of the instrument starting with those at the lower left hand part of the panel and proceeding clockwise around the face of the instrument.

1. MODULATION FREQUENCY SWITCH.

This control selects any one of eight fixed audio frequencies between 50 cycles and 15 kilocycles for either frequency or amplitude modulation.

2. MODULATION SELECTOR SWITCH.

Either frequency or amplitude modulation may be obtained by setting this switch to the proper position. Modulation may also be turned off.

3. VERNIER FREQUENCY DIAL.

This dial is divided into 100 divisions and is coupled to the Main Frequency Dial through a 24:1 gear train, providing a total of 2400 logging divisions for each r-f range.

4. DEVIATION RANGE SWITCH.

This rotary type switch selects three modulation meter deviation ranges, 0-24 kc., 0-80 kc., and 0-240 kc.

5. MODULATION METER.

Four Modulation Meter scales are provided; 0-24 kc. deviation in 1 kc. increments, 0-80 kc. deviation in 5 kc. increments, 0-240 kc. deviation in 10 kc. increments, 0-50% amplitude modulation, with calibration marks at 30% and 50%, and 0-100% amplitude modulation with a calibration mark at 100%. The 100% scale is for use only when an external oscillator is employed.

6. FM DEVIATION CONTROL.

A continuously variable control for adjusting the frequency deviation on any of the three ranges 0-24 kc., 0-80 kc., or 0-240 kc.

7. MODULATION METER SWITCH.

By means of this control the Modulation Meter may be switched to either the FM or AM modulating system to indicate the degree of modulation present.

8. AMPLITUDE MODULATION CONTROL.

A continuously variable control for adjusting the amplitude modulation level when either the internal AF oscillator or an external AF oscillator is used.

9. R-F MONITOR METER.

The R-F Monitor Meter is used to standardize the power level of the last r-f amplifier stage. In operation the meter pointer is set to the red calibration line on the meter scale.

10. R-F MONITOR CONTROL.

This adjustment sets the R-F Monitor Meter to the proper reference level such that the output attenuator calibration is direct reading in microvolts.

11. MAIN FREQUENCY DIAL.

The Main Frequency Dial has one frequency calibration covering from 175-250 megacycles. An inner scale is divided into 24 equal divisions for use with the Vernier Frequency Dial.

12. PULSE MODULATION JACK.

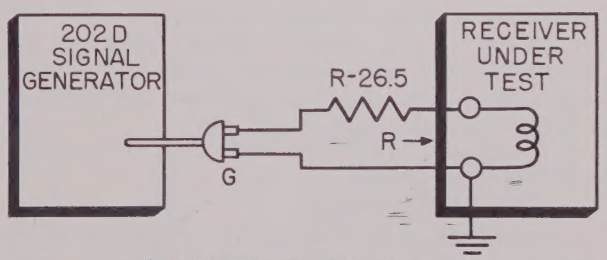
The Pulse Modulation Jack is provided to permit direct connection of an external modulation voltage source to the screen of the final stage for pulse and square wave modulation. When this connection is made the modulation meter and internal circuits are disconnected from the screen element.

13. R-F OUTPUT ATTENUATOR.

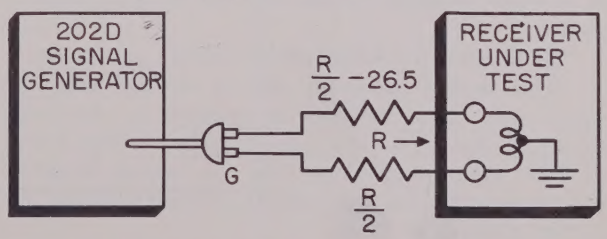
The R-F Output Attenuator Dial is calibrated directly in microvolts output at the output cable terminals. It is standardized by setting the pointer of the R-F Monitor Meter to the red calibration mark on the meter scale.

c. OUTPUT CONNECTIONS.

In order to match properly the input impedance of a receiver under test, it may be desirable to add a



(a) UNBALANCED INPUT TO RECEIVER
R=INPUT IMPEDANCE TO RECEIVER



(b) BALANCED INPUT TO RECEIVER

Fig. 3. Receiver Connections

resistor in one or both sides of the r-f line from the signal generator as shown in figure 3.

For the case of the unbalanced receiver input an impedance match may be obtained by connecting the proper resistance to the "high" signal generator terminal and connecting the ground of the signal generator to the receiver ground (figure 3a).

To use the signal generator with a receiver having a balanced input impedance, connections should be made according to figure 3b. As a check for the possibility of the ground between generator and receiver being low enough to shunt the padding resistor in the low side of the r-f line, the power plug of the generator may be moved to a different outlet. Negligible change in readings should be observed.* Resistors independent of frequency should be used to avoid errors due to reactance.

d. SIMULTANEOUS FM AND AM.

For certain tests simultaneous FM and AM is sometimes desired. The 202-D FM Signal Generator, in combination with an external low distortion audio oscillator, may be used for this purpose provided that the audio oscillator is capable of developing approximately 5 volts across a 1500 ohm load, the FM requirement for 240 kc. deviations.

In use the external audio oscillator is connected to the FM external binding posts, the MODULATION SELECTOR SWITCH set to AM, and the levels of each type of modulation independently set on the MODULATION METER by operation of the MODULATION METER SWITCH, FM DEVIATION CONTROL, and AMPLITUDE MODULATION CONTROL.

CAUTION:

Use of an external audio oscillator for AM, with the INTERNAL MODULATION OSCILLATOR switched to FM, will result in interaction between modulation circuits when both oscillators are operating at or near the same audio frequency.

3. SPECIFICATIONS.

a. R-F RANGE.

Overall frequency coverage 175-250 megacycles in one range, accurate to ±0.5% after a warm-up period of one hour. The main frequency dial is also calibrated in 24 equal divisions for use with the vernier frequency dial.

b. VERNIER FREQUENCY DIAL.

The vernier frequency dial is divided into 100 equal scale divisions and is coupled to the main frequency dial by a 24:1 gear train, providing a total of 2400 logging divisions over the tuning range of the instrument. The approximate frequency change per vernier division is 35 kc.

c. R-F OUTPUT VOLTAGE.

The maximum open circuit output voltage from the BNC type R-F output jack at the front panel is about 0.4 volt. With the standard output cable (type 501-A) attached, the maximum calibrated output voltage at the cable terminals is 0.2 volt. When the r-f monitor meter is set to the red calibration line and the standard output cable attached, the r-f output attenuator is direct reading in microvolts and continuously adjustable from 0.1 microvolt to 0.2 volt.

d. R-F OUTPUT IMPEDANCES.

The R-F output impedance of the signal generator as seen looking in at the BNC type front panel connector is 53 ohms resistive. With the standard output cable attached, the r-f output impedance as seen looking in at the output cable terminals is 26.5 ohms resistive.

e. FREQUENCY MODULATION.

Three frequency deviation ranges, 0-24 kc., 0-80 kc., and 0-240 kc. are provided, each continuously adjustable. The 0-24 kc. deviation scale is calibrated in increments of 1 kc., the 0-80 kc. scale in increments of 5 kc. and the 0-240 kc. scale in increments of 10 kc.

f. AMPLITUDE MODULATION.

1. Internal Modulation.

Utilizing the internal audio oscillator, amplitude modulation may be obtained over the range of 0-50%, with meter calibration points provided at 30% and 50% modulation points.

2. External Modulation.

By using an external audio oscillator, the R-F carrier may be amplitude modulated to substantially 100%. For this purpose the modulation meter has a scale calibration point at 100%.

3. Pulse Modulation.

A front panel jack is provided which permits direct connection of an external modulation voltage source to the screen of the final stage for pulse and square wave modulation. When this connection is made the modulation meter and internal circuits are disconnected from the screen element. Approximately 75 volts is required to maintain the carrier at its normal level and about minus 3 volts will shut the carrier off.

g. DISTORTION.

1. FM: The overall FM distortion at 75 kc. is less than 2% and at 240 kc. less than 10%.

2. AM: The distortion present at the r-f output for 30% amplitude modulation is less than 3% and for 50% AM less than 6.5. At 100% the distortion is 12% to 15% depending upon the modulating frequency.

**Various methods of obtaining push pull voltage from an unbalanced generator output are discussed in the RCA Review, Vol. VI, April 1942, Number 4, in an article entitled "Receiver Input Connections for U-H-F Measurement" by John A. Rankin.*

b. SPURIOUS R-F OUTPUT.

All spurious r-f output voltages are at least 25 db. below the desired fundamental. Total RMS spurious FM from the 60 cycle power source is down more than 50 db., with 75 kc. deviation as a reference level.

i. FIDELITY CHARACTERISTICS.

The deviation sensitivity of the FM modulation system as a function of frequency is constant from D.C. to 100 kc. At 200 kc. the deviation as indicated on the modulation meter is about **6.25 db. higher** than the true value.

The amplitude modulation system, with the modulation potentiometer at maximum position, is substantially flat from 30 cycles to 100 kc. At 200 kc. the indicated per cent modulation is approximately **7.2 db. lower** than the actual carrier modulation. With the modulation potentiometer at one half of full rotation setting, the amplitude modulation system is within 1.0 db. from 100 cycles to 10 kc. At 30 cycles and at 70 kc. the indicated per cent modulation is approximately 4 db. lower than the actual carrier modulation.

Direct connection to the screen element of the final output stage permits square wave or pulse modulation to be applied from an external voltage source. Under these conditions the rise time of the modulation carrier envelope is less than 0.25 microseconds and the decay time less than 0.8 microseconds.

j. INTERNAL AF OSCILLATOR.

The internal AF Oscillator may be switched to provide either frequency or amplitude modulation; it may also be switched off. External binding posts permit the use of an external AF oscillator for either AM or M. The internal oscillator and an external AF oscillator may be used simultaneously, thus producing either FM or AM at two modulation frequencies simultaneously. With the internal oscillator switched for AM, an external AF oscillator may be used simultaneously to frequency modulate the AM signal.

The internal AF oscillator provides eight fixed frequencies which may be selected by a rotary type switch -50, 100, 400 cycles and 1, 5, 7.5, 10, 15 kilocycles, accurate to within 5%. Harmonic distortion, in general, is less than 0.5%.

The output voltage of the internal oscillator is available at the external binding posts for synchronizing or other purposes.

k. EXTERNAL MODULATION REQUIREMENTS

1. Frequency Modulation.

The deviation sensitivity is 50 kc. per volt on the 0-240 kc. position. For external FM the input impedance is 1500 ohms.

2. Amplitude Modulation.

Approximately 45 volts are required for 50% modulation and 100 volts for 100% modulation. For external AM the input impedance is 7500 ohms.

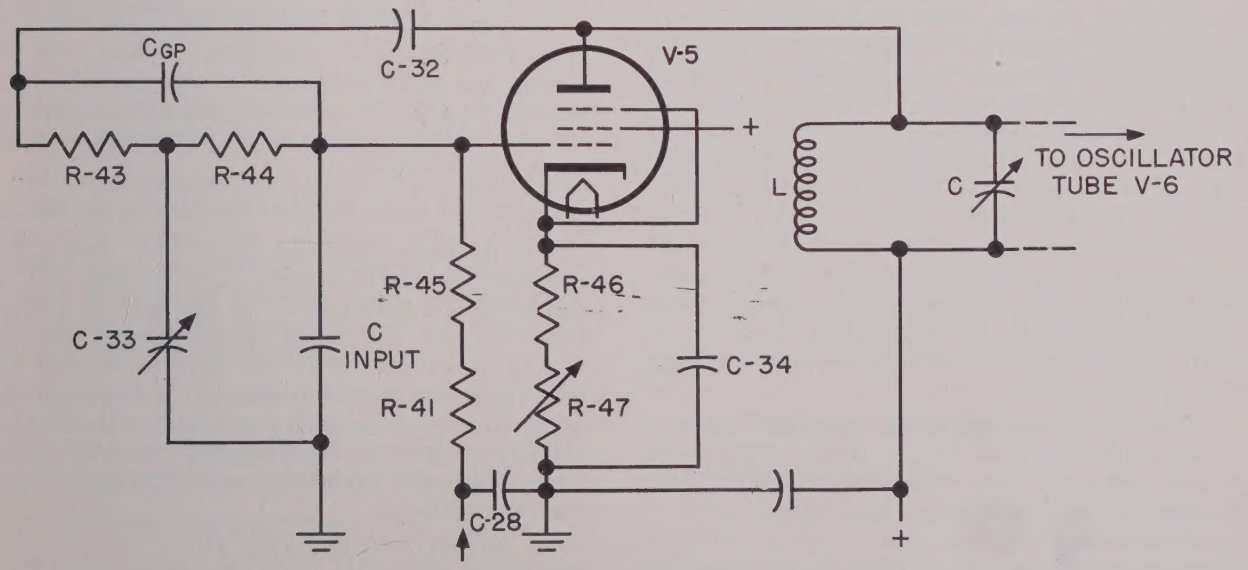


Fig. 4. Basic Reactance Modulator Circuit

3. Audio Voltage for External Use.

There is available at the FM external oscillator binding posts about 5 volts a.c. maximum and at the AM external oscillator binding posts posts, 50 volts maximum.

l. TUBE COMPLEMENT.

Audio Oscillator	6J5, 6V6GT/G	(V1, V2)
Rectifier	5Y3GT/G	(V3)
Voltage Regulator	VR-150	(V4)
Reactance Modulator	6AK5	(V5)
R-F Oscillator	6C4	(V6)
Doubler Stage	6AK5	(V7)
Doubler and Output	6AK5	(V8)
Ballast Resistor	6H-6	(R18)

m. POWER REQUIREMENTS.

The 202-D FM Signal Generator is designed for use with 115 volts, 50-60 cycles. It will operate satisfactorily, however, over a voltage range from 105-125 volts without changing the r-f frequency by more than 0.05%. A two ampere fuse is placed in one side of the a-c line for protective purposes. Power consumption is 65 watts.

n. DIMENSIONS AND WEIGHT.

Outside cabinet dimensions: 17" high, 13-½" wide, 11-½" deep. Weight: 35 pounds.

4. THEORY OF OPERATION.*

a. REACTANCE MODULATOR CIRCUIT (Fig. 4).

A 6AK5 tube (V5) operating as an inductive element across the tank circuit of the 6C4 (V6) oscillator circuit is employed for reactance modulation. In order to maintain constant frequency deviation sensitivity over the entire tuning range of the instrument the amount of inductance injected by V5 is made to vary directly as the carrier frequency. This is accomplished (Fig. 4) by a bridged tee network consisting of R43, R44, C33, the grid plate capacitance of V5, and the grid cathode capacitance of V5. Although this circuit arrangement is capable of producing fairly constant deviation with fixed components, C33 is made variable and ganged with the oscillator tuning condenser to provide the precision of deviation calibration required in a signal generator.

Resistor R50 serves to bleed the proper amount of current through R46, R47 to permit operation of V5 over the most linear portion of its characteristics (Fig. 8).

The cathode resistors R46 and R47 which provide bias for V5 are bypassed by C34 for radio frequencies only and degeneration takes place at audio frequencies. Resistor R47 is used to adjust the amount of degeneration present in order to provide the desired deviation sensitivity.

Switch S3 reduces the modulating voltage applied at the reactance tube to one third when operated from the 0-240 kc. deviation position to the 0-80 kc. deviation position, and to one tenth when operated from the 0-240 kc. deviation position to the 0-24 kc. deviation position.

For FM, an audio modulating voltage is applied directly to the grid of V5, the reactance tube, through an r-f filter which prevents stray r-f currents from leaking out of the shielded portion of the instrument.

b. AF OSCILLATOR (Fig. 8).

The AF oscillator employed is quite free from distortion having, in general, total harmonic content of less than 0.5%. The conventional Wein bridge type of R-C oscillator is user. The series and shunt R-C combinations required to provide the desired modulating frequencies are mounted directly on the rotary type selector switch and are connected by means of two leads to the AF chassis which mounts the oscillator tubes and components. Approximately 50 volts is obtained from the plate of the 6V6 tube (V2) for providing amplitude modulation up to 50%, the exact value being controlled by adjustment of R12 which regulates the amount of negative feedback voltage applied to the cathode of V1. For amplitude modulation up to 100%, an external oscillator is required capable of supplying 100 volts to a 7500 ohm lead.

c. R-F OSCILLATOR (Fig. 8).

A tuned plate r-f oscillator covers the frequency range from 43.75-62.50 megacycles. Tuning over this range is accomplished by means of capacitor C39 which is ganged to the two other variable tuning capacitors C45 and C50. The plate of V6 is normally operated at about 150 volts d-c.

d. AMPLIFIER DOUBLER STAGE (Fig. 8).

A frequency doubling stage (V7) follows the oscillator, and serves the two fold purpose of (1) permitting the oscillator to be operated at a lower frequency and (2) providing the desired isolation between oscillator and output stage to improve frequency stability. A further advantage is that it provides sufficient drive to saturate the output stage and thus remove any spurious amplitude modulation up to this point. This stage is self-biased and is arranged to track with the oscillator.

e. OUTPUT STAGE (Fig. 8).

The output stage employs a 6AK5 tube (V8) operating as a Class C doubler. Amplitude modula-

**Theory of operation and design information are given in an article in the November, 1946 issue of Electronics Magazine entitled "Design of F-M Signal Generator" by Donald M. Hill and Murray G. Crosby.*

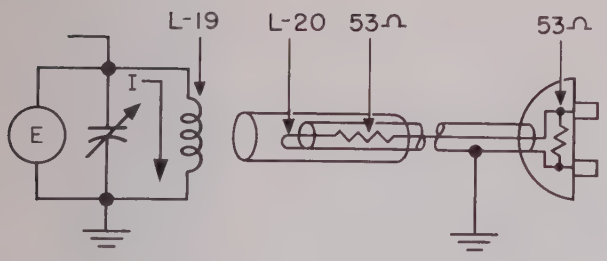


FIG. 5a

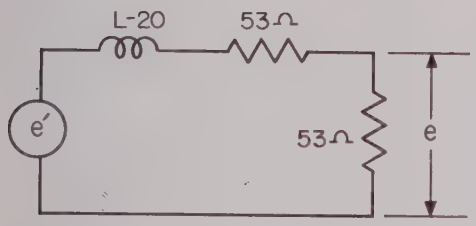


FIG. 5b

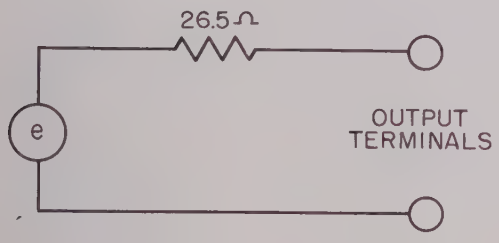


FIG. 5c

Fig. 5. Output Attenuator Equivalent Circuit

tion is obtained by modulating the screen element of V8, sufficient isolation from the D-C supply having been provided by the 50 henry choke, L-2.

Pulse Modulation Jack J-1 provides a means for introducing an external voltage source to pulse or square wave modulate the r-f carrier. When this connection is made the modulation meter and internal circuits are disconnected from the screen. Resistor R-26 is in series with the screen lead to damp out any transients which might otherwise occur.

Capacitors C-29, C-30 and C-31 associated with the filter net-work for the screen lead of V8 have been kept as small as possible in order to provide greatest possible high frequency response for the AM system.

f. OUTPUT ATTENUATOR.

A piston type r-f output attenuator having an internal impedance of 53 ohms is inductively coupled to the tank circuit inductor of the final stage. To provide continuously adjustable attenuation, the pickup loop of the attenuator is movable along the axis of the attenuator tube by means of a rack and pinion drive.

The RG58/U output cable and BNC panel fittings are of 53 ohm impedance and the output cable is terminated by a 53 ohm carbon resistor.

Figure 5 shows the basic design of the output attenuator system. The voltage induced in the attenuator coupling loop L_{20} in figure 5a is:

$$e' = I\omega M = \frac{E}{\omega L_{19}} \times \omega K \sqrt{L_{19} L_{20}} = EK\sqrt{\frac{L_{20}}{L_{19}}}$$

where $\omega = 2\pi$ times the frequency, K is the coefficient of coupling between L_{19} and L_{20}, and M is the mutual inductance between L_{19} and L_{20}.

This equation shows that e' is a function of the tank voltage E and the coefficient of coupling K only. K is controlled by the attenuation law of the piston attenuator while E is monitored by the output monitor meter.

It can be seen from figure 5b that the voltage e across the terminating resistor is:

$$e = \frac{53e'}{106 + j\,(\omega L_{20})} = \frac{53e'}{\sqrt{(106)^2 + (\omega L_{20})^2}}$$

Since L_{20} is less than 0.01 microhenry, $(\omega L_{20})^2$ can be neglected in comparison with $(106)^2$ and:

$$e = \frac{e'}{2}$$

Neglecting L_{20} in figure 5b, an application of Thevenin's theorem yields the equivalent circuit shown in figure 5c. Thus the generator can be represented as a source voltage e in series with a resistance of 26.5 ohms. The attenuator dial is calibrated in terms of the open circuit output voltage e (Fig. 5c) and is direct reading in microvolts from 0.1 microvolt to 0.2 volt when the output monitor meter is set to the red reference line.

If the load impedance is not large compared with 26.5 ohms, the voltage applied to a load connected at the output terminals can be calculated by using the equivalent circuit of figure 5c.

5. MAINTENANCE INSTRUCTIONS.

a. R-F UNIT (Fig. 6).

This unit has been carefully adjusted and calibrated at the factory to meet the specifications listed in this instruction book. Specialized testing equipment and procedures are required which make field adjustments and replacements in the unit difficult and undesir-

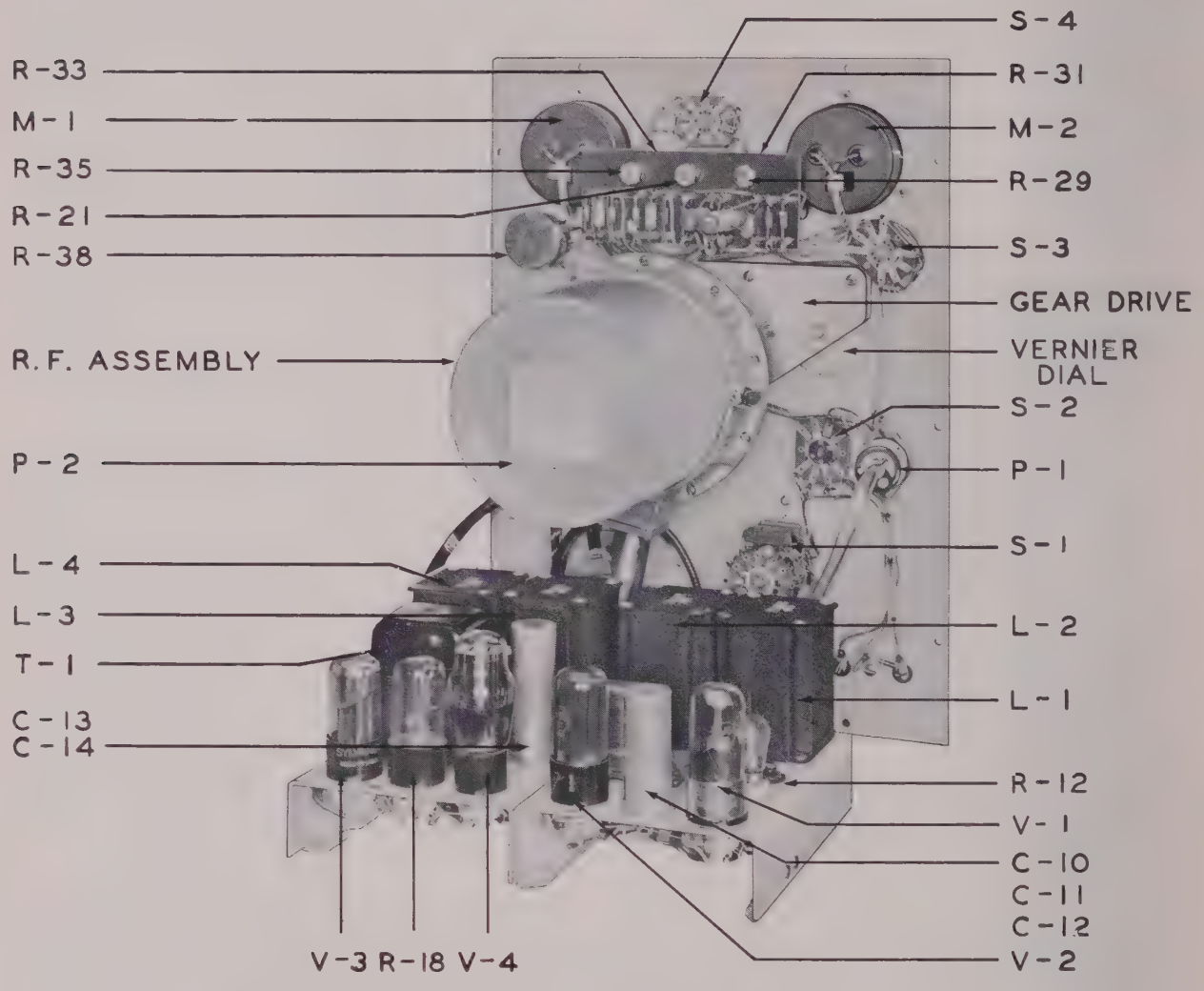


Fig. 6. Rear View of Panel Assembly, Power Supply, and Audio Oscillator

able. For this reason the aluminum shield has been sealed against removal. Since the instrument is guaranteed for workmanship, materials, and performance, instructions for its return to the factory should be immediately obtained if it is found to be unsatisfactory in operation. THIS GUARANTEE, HOWEVER, IS ONLY VALID PROVIDED THE SEAL ON THE RF SHIELD IS UNBROKEN.

The 60 cycle heater voltage between pin 5 of plug 2 and ground (Fig. 6) should measure 6.3 volts. If the r-f unit is found to be inoperable and this voltage measures in excess of 7 volts, the trouble is probably due to an open heater circuit at one of the r-f tubes. Continued operation of the instrument under this condition will damage the other r-f tubes.

b. VR-150 REGULATOR TUBE (Fig. 7).

When replacing this tube (V4) it is desirable to check its current drain by placing a milliammeter in series with the plate and adjusting R19 for a 7 milliampere plate current with the input voltage to the power transformer primary set at 105 volts. The adjustment will insure proper operation of the power supply over a line voltage range of 105-125 volts.

c. AMPLITUDE MODULATION ADJUSTMENT.

If desired, the degree of amplitude modulation on the modulation meter can be checked by suitable mixing the output of the generator with another signal source such that a difference frequency of approximately 100-150 kc. is produced. This difference frequency can

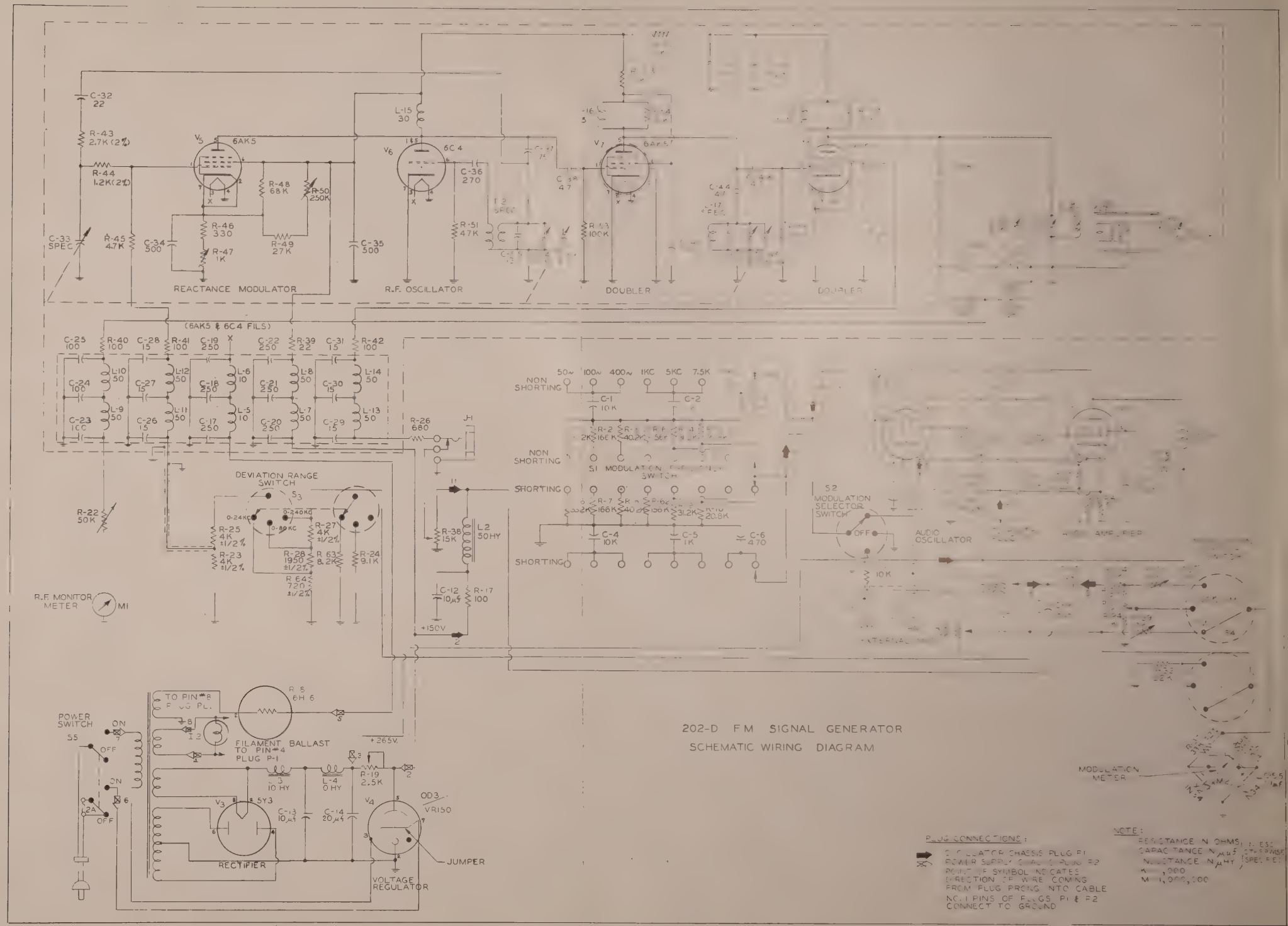


Fig. 8. Schematic Wiring Diagram of 202-D FM Signal Generator

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